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Procedures for Selection of Countermeasures for Hazardous Substance Releases

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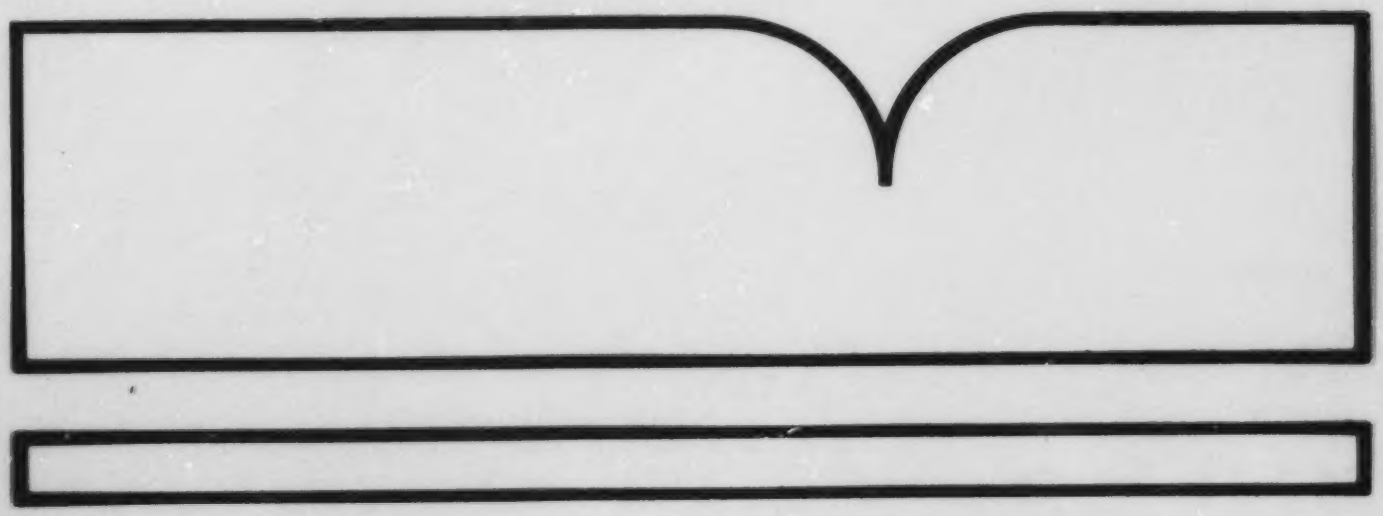

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PROCEDURES FOR SELECTION OF COUNTERMEASURES FOR HAZARDOUS SUBSTANCE RELEASES

by

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Contract Number 68-03-3014

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16. ABSTRACT

When a release of hazardous substances has occurred or threatens to occur, federal, state, local government or industrial personnel may have to assume responsibility for immediate and planned removal. This is the principal cleanup and treatment phase, which sometimes is followed by a remedial action phase. Remedial action is not addresed here.

This paper describes a methodology to assist response personnel in selecting optimum countermeasures consisting of (1) assessment of the release site to identify hazardous substances or wastes, media impacted and site-specific parameters (such as topography, climate, and proximity to inhabited areas); (2) insertion of results of (1) into Tables "A" which classify the known hazardous substances according to physical behavior and specific hazards on release to the known media; (3) insertion of results of (2) into Tables "B" which indicate one or more technically feasible countermeasures, ie., on-site or off-site cleanup or treatment processes; and (4) making a final or optimum selection from these processes through use of Tables "C" which apply criteria and constraints such as availability, cost speed or deployment and site-specific parameters.

Examples are included of the four types of decision-making procedures listed above. Procedure (1) makes use of a flowchart to translate close and remote observations into decision and action items at the site. Procedure (2) uses a set of seven tables which classify the CERCLA hazardous substances by phase (liquid, solid, gas), specific gravity (sinkers/floaters), and solubility (high/low). For each substance or group of substances, the physical behavior and the specific hazards on release are designated. In Procedure (3) several Tables indicate the various technically feasible removal countermeasures including physical, chemical, biological treatments, or "no treatment". Lastly Procedure (4) uses Tables which select the optimum countermeasures from those identitfied as feasible in (3).

The paper concludes with a worked example of the application of the entire methodology to a real situation. Given a reasonable amount of knowledge about the release, a person with limited background can use the methodology to arrive at workable removal countermeasures.

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INTRODUCTION

This paper describes a methodology designed to assist federal, state, local government, and industry personnel who may find it necessary to respond to a release, or threat of a release, of hazardous substances designated in

CERCLA Section 102, excluding oil. Currently over 600 substances have been designated. The methodology applies to releases and sites of all kinds, including spills (transportation and non-transportation related), and hazardous waste sites.

The methodology is intended for field use and guides the responder through a series of decisions and actions to be taken at the site of the release or potential release. These actions are mandated by the National Contingency Plan (40 CFR Part 300, dated July 16, 1982) which in Subpart F, Hazardous Substance Response, lists 6 phases in more or less chronological order:

I. Discovery and Notification

II. Preliminary Assessment

III. Immediate Removal

IV. Evaluation and Determination of Appropriate Response

V. Planned Removal, and

VI. Remedial Action.

This methodology encompasses portions of Phases II through V. It is assumed that an actual or potential hazardous substance release exists. The methodology consists of four procedures, to be applied in sequence.

Procedure (1) provides guidelines for a situation assessment which results in the identification of the hazardous substance and medium (atmosphere, surface water, ground) receiving the release. This information is then used as input to Procedure (2) in which the physical nature of the hazardous substance involved and the associated hazards are found from Tables A. Procedure (3) uses the information from Tables A as input to find various

technically feasible countermeasures from Tables B. Procedure (4) selects from the countermeasures in Tables B those considered optimal in light of applicable criteria and parameters. Here the term countermeasure includes physical, chemical, and biological cleanup, treatment and disposal processes to be carried out on-site or off-site. Countermeasure selection criteria include considerations of the degree of cleanup achievable, environmental factors, logistics, safety, and cost. One alternative to always consider is that of taking no immediate action and relying on isolation alone.

The paper also lists field-worthy countermeasures, defined in terms of their characteristics, advantages, and disadvantages. Having been presented at the conclusion of Procedure (4) with one or more optimal countermeasures, the responder makes the final choices by referring to this critical listing. An important use of the list is when a release comprises two or more hazardous substances and it is crucial that syner- gistic effects be considered. The application of different countermeasures in parallel or in series must then be closely examined. The countermeasures listing was compiled from examination of over 200 recent primary sources of which a short bibliography of the most useful sources is appended. The paper concludes with an example of the application of the methodology, making use of Tables A,B and C.

In view of the over 600 hazardous substances and large number of countermeasures to be covered, this paper presents only excerpts from Tables A, B and C and the countermeasures listing because of space limitations. Complete tables and listings will be found in a manual on this subject to be published in the near future.

SITUATION ASSESSMENT (Procedure 1)

At the start it is assumed that an incident or accident took place, possibly involving a hazardous substance. The responder's first step is to find out if indeed a hazardous substance was involved, and if so, whether a release occurred or is threatening to occur. Procedure (1), the assessment of the situation and decision what actions to take, is contained in the Situation Assessment Flowchart (Figure 1). Early on, the responder must make observations of the site in question, either remotely and/or by entering the site, in order to obtain essential data on the site. These data are shown on the Site Assessment Checklist (Figure 2).

In short, the responder should trace through Figure 1 from top to bottom and from left to right carrying out action items (in rectangular boxes) as necessary in order to obtain sufficient information to complete Figure 2. This checklist will be needed as input to the Tables A and later to the Tables C in Section 3 to provide information for the criteria used in selecting the optimal countermeasures.

The output at the bottom of the flowchart will establish the substance (or substances) released, its form (solid, liquid, gas), the medium into which released (water, ground, atmosphere) and the physical behavior on release (sink/ float, soluble/insoluble). These, via offpage connectors 3,4, or 5 guide the responder to the proper Table A.

As mentioned earlier, some items on the Site Assessment Checklist can be ascertained remotely, without approaching or entering the site. However, entry and control of the site are generally required for situation assessment. Proper safety precautions are paramount in site assessment activities, especially when entering a site containing unknown hazards. The site must be

monitored and necessary measurements made to establish the presence and concentrations of any hazardous substances. Contaminants from the site must also be controlled to prevent exposure of personnel and the general public.

HAZARDOUS SUBSTANCE CHARACTERISTICS (Procedure 2)

From Procedure (1) the responder will have determined the name of each hazardous substance (if more than one are present) and the medium or media impacted. The Tables A should then be consulted to find out the physical behavior class of the substance on release (float/sink, soluble/insoluble, air disperse, etc.), its chemical class, and its hazards in addition to toxicity. Two typical illustrations are given for a release on water. Figure 3 is the complete Table A for Insoluble Floaters, and Figure 4 is an excerpt from the Table A for releases on water on substances of all specific gravities (floaters and sinkers) and solubilities (soluble and insoluble). Three other Tables A, not shown here, cover liquid releases on land, particulate solid releases on land, and compressed gas releases in air. The CAS (Chemical Abstract Service) number for each substance is also included on the Tables A for standardizing substances known by more than one name.

FEASIBLE COUNTERMEASURES (Procedure 3)

From Procedure (2) the chemical class has been found and this determines the technically feasible countermeasure from the Tables B which parallel the Tables A, i.e., one table for each class of physical post-release behavior. Figure 5 is the Table B for Insoluble Floaters, corresponding to Figure 3. Applicable countermeasures appear at the top of the table, divided into sections on containment, displacement and treatment. Check marks indicate countermeasures which are technically feasible for the various chemical

functional groups. The responder can thus find, in general, several countermeasures which could be used for each hazardous substance.

One option which should be given consideration in any spill situation is containment, but "no treatment". Inherent in this strategy is the expectation that certain natural processes will neutralize the threat. There is need for constant monitoring of the spill for any potential danger to the environment and population. If the situation deteriorates, real treatment may become necessary. As a countermeasure, no treatment is applicable only to spill scenarios where the long-term threat is minimal. For this reason substances such as heavy metals, organometallics, and halogenated compounds should never be treated in this manner. In general, only those spills involving substances which are amenable to biodegradation, evaporation or perhaps oxidation by UV light should be considered candidate for no treatment.

COUNTERMEASURE SELECTION CRITERIA (Procedure 4)

It remains now to optimize the feasible countermeasures from Procedure (3) by applying non-technical criteria, such as logistics, availability, efficiency, and cost. This is done in the Tables C, again one for each of the classes of post-release physical behavior. The Tables C list numerical or descriptive values for each of the selection criteria (e.g., deployment time, cost dollars, cleanup efficiency, etc.) as they apply to each countermeasure. Now one should again refer to the Site Assessment Checklist (Figure 2) which resulted from the Situation Assessment (Figure 1). The responder can now select the specific countermeasures which are optimum for the constraints imposed by the particular release situation.

A typical Table C is shown in Figure 6 for insoluble floaters. Here the

countermeasures are listed in the extreme left column; the limitations, requirements, costs and comments are arranged along the top edge of the table.

Further refinement of countermeasure selection is possible by perusal of the Description of Countermeasures.

DESCRIPTION OF COUNTERMEASURES

This is a continuous listing of all the countermeasures considered figuratively, divided into sections on (1) Containment and Displacement, (2) Physical Treatment, (3) Chemical Treatment, (4) Open Burning, (5) Biological Treatment, In-Situ, and (6) Ultimate Disposal/Destruction. Figure 7 is an index to second-order and third-order headings within the six main sections.

The following types of information are given in the listing:

- o Description of the countermeasure.
- o Applicability of and recommendations for the countermeasure in field use.
- o Precautions in human and biota toxicity.
- o Limitations - environmental, demographic, and legal, e.g., permitting .
- o Requirements - power supply, manpower, and special equipment or supplies.
- o Availability of equipment and supplies.
- o Costs for both durable equipment and expendable supplies.

An example of the contents of the listing appears in Figure 8 which is an excerpt starting with Section (2) Physical Treatment, and showing Absorption information.

BIBLIOGRAPHY

The data contained in Tables B, Tables C and in the Description of Countermeasures (illustrated in Figures 5, 6, 7 and 8) was based on a critical review of source material generated during the last few years on various aspects of hazardous substance pollution and cleanup. Over 200 sources were evaluated and cross-checked. Certain handbooks, compendia and conference proceedings were found to include much of the pertinent countermeasure information in convenient form, and these major reference works are listed in Figure 9.

EXAMPLE OF APPLICATION

Spill Scenario

A tank truck carrying several thousand gallons of a liquid chemical overturns on a suburban highway bordering a slow-moving stream. The tank is fractured and discharges a liquid which runs off the road to the stream bank and thence into the stream. The stream eventually empties into a major water course used for recreation and as a source of potable water. There is light drizzle, but negligible wind. Police and fire department units were first on the scene, established a road block to isolate the site, took the injured driver to an emergency hospital and phoned your agency who dispatched you to the site to take charge of countermeasures. On arrival you observe and/or are given the information above.

Situation Assessment

Perusing Figure 1 from the top, you know a spill has occurred. Observation with binoculars from a safe distance leads you to conclude that

the spill is not massive. You need to find out the name and nature of of the spilling liquid. You look for the diamond-shaped placard on the end of the tank, however, it is not visible to you. But you can spot through your binoculars the duplicate of that placard on the side of the cab. It carries the red flame symbol and the number 3, as well as the ID number 1100. By reference to the DOT Hazardous Materials Emergency Response Guidebook (Item 13 on Figure 9), you find that this ID number refers to Allyl Chloride, and from the placard it is obviously flammable. But you still don't know if it is a toxic substance designated under CERCLA.

Hazardous Substance Characteristics

Since you are faced with a release on water you refer to the appropriate Table A (Figure 4) which identifies Allyl Chloride (CAS No 107-05-1) as a toxic compound which is also flammable with toxic products, chemically in the alkyl halide and olefin classes, and physically an insoluble floater. You then refer to the Table A for Insoluble Floaters (Figure 3) and confirm the identification.

Feasible Countermeasures

Next you check the Table B for Insoluble Floaters for the alkyl halide and olefin classes (Figure 5). The check marks indicate that technically feasible are all forms of containment (dams, booms, barriers) and displacement (skimming, vacuum pumping) and certain treatment processes common to both classes (gravity separation, activated carbon, chemical dispersion and biological treatment).

Selection of Countermeasures

In view of the site assessment and spill scenario you must select a

method of preventing the floating liquid from reaching the major water body and, next, getting it out of the stream to shore for treatment and disposal. You look at the Table C for Insoluble Floaters (Figure 6). Of the containment countermeasures booms are optimal - they will operate in low wind and current conditions, are not affected by precipitation, can be deployed rapidly, are relatively inexpensive, and they will function with the neat liquid (it is an insoluble floater). The preferred displacement countermeasure is a suction head skimmer as it effectively removes the neat substance with relatively little water entrainment. Further, access is good, the highway being next to the stream, so that a vacuum truck can be used to collect the discharge from the skimmer. You therefore (1) measure or estimate the dimensions for one or more booms and order them installed at a downstream point so most of the liquid can be captured, and (2) estimate the rate or amount of liquid spilling and order a skimming vacuum pumping unit. It is assumed that you will have access to communication equipment (police car) and will have brought from your office information on equipment and costs of the closest cleanup contractors. If you want to educate yourself more, read the appropriate sections on containment and displacement methods in the Countermeasure Descriptions (refer to Figure 7 and Figure 8).

Now you should consider the treatment/disposal methods. The vacuum truck will collect the hazardous liquid in a tank and can transport the contents to an off-site treatment location. Checking the four treatment methods listed as feasible: gravity separation is listed as capable of gross cleanup of neat substances without use of special equipment or highly trained personnel; activated carbon applies to substances in solution as a polishing step;

chemical dispersion is an in-situ method which may require permits; and biological treatment is a lengthy process applicable to substances in solution and also may require permits. You may want to consult Countermeasures Descriptions (see Figure 7 and Figure 8) for more details. You will select the gravity separation method for initial cleanup, followed by a polishing step if the solubility, though very small, is large enough to result in a dissolved fraction of Allyl Chloride which could be troublesome, when the separated water is tested. If a polishing step is needed, you choose an activated carbon column. Chemical dispersion is unsuitable in view of the ultimate potable water use of the stream, and biological treatment may be marginal for a chlorinated compound. Since you will have sufficient time to make decisions about a possible polishing step, you can consult the original sources on countermeasures which are listed in the Bibliography of the complete Manual.

DISCLAIMER

This paper has been reviewed by the Municipal Environmental Research Laboratory - Cincinnati, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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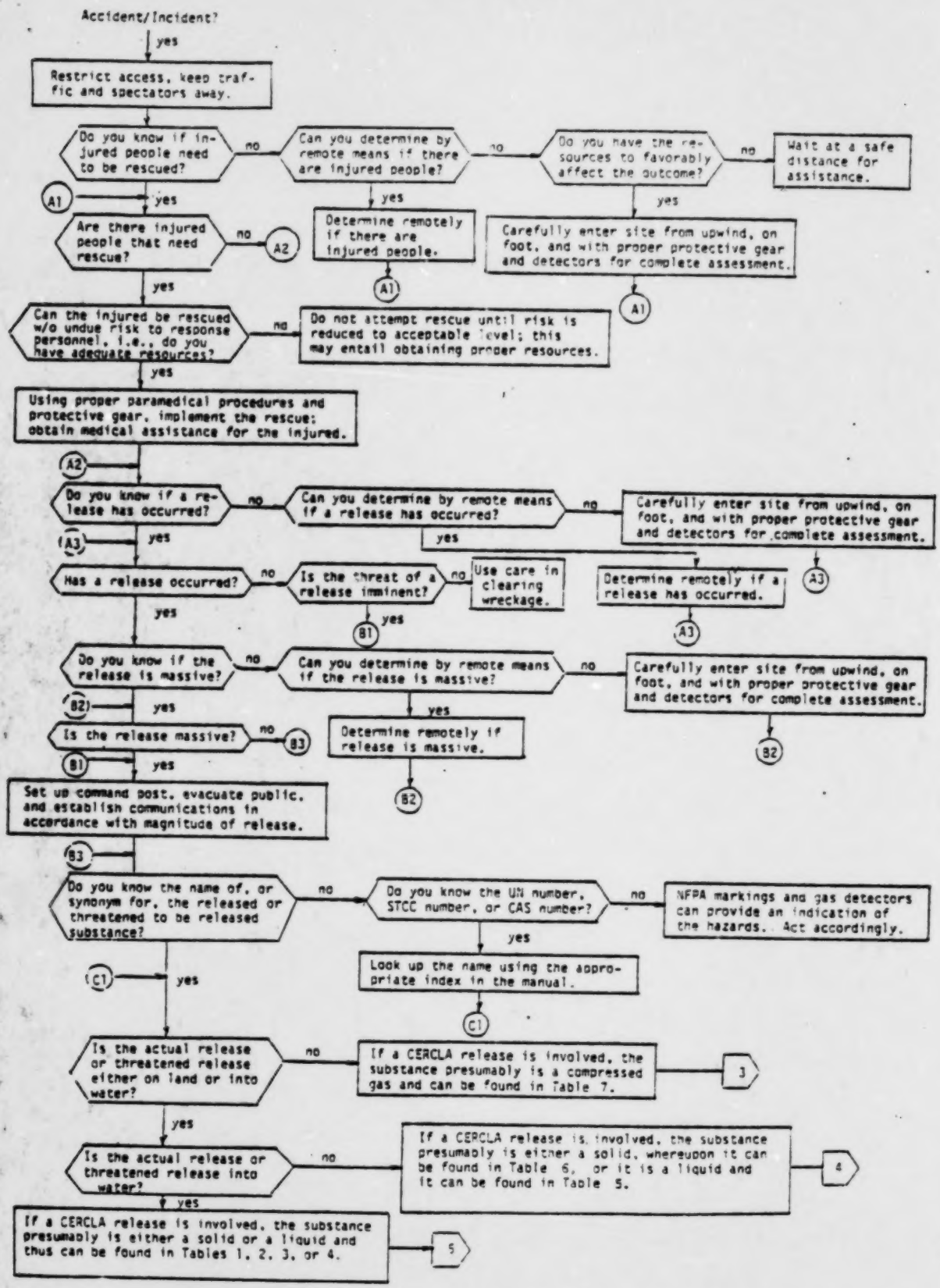
Accident/Incident?
yes
Restrict access, keep traffic and spectators away.
Do you know if injured people need to be rescued?
no
Can you determine by remote means if there are injured people?
no
Do you have the resources to favorably affect the outcome?
no
Wait at a safe distance for assistance.
A1
yes
yes
yes
Are there injured people that need rescue?
no
A2
Determine remotely if there are injured people.
Carefully enter site from upwind, on foot, and with proper protective gear and detectors for complete assessment.
A1
A1
yes
Can the injured be rescued w/o undue risk to response personnel, i.e., do you have adequate resources?
no
Do not attempt rescue until risk is reduced to acceptable level; this may entail obtaining proper resources.
yes
Using proper paramedical procedures and protective gear, implement the rescue; obtain medical assistance for the injured.
A2
Do you know if a release has occurred?
no
Can you determine by remote means if a release has occurred?
no
Carefully enter site from upwind, on foot, and with proper protective gear and detectors for complete assessment.
A3
yes
yes
A3
Has a release occurred?
no
Is the threat of a release imminent?
no
Use care in clearing wreckage.
Determine remotely if a release has occurred.
A3
yes
yes
B1
B1
Do you know if the release is massive?
no
Can you determine by remote means if the release is massive?
no
Carefully enter site from upwind, on foot, and with proper protective gear and detectors for complete assessment.
B2
yes
yes
Is the release massive?
no
B3
Determine remotely if release is massive.
B2
B2
B1
yes
Set up command post, evacuate public, and establish communications in accordance with magnitude of release.
B3
Do you know the name of, or synonym for, the released or threatened to be released substance?
no
Do you know the UN number, STCC number, or CAS number?
no
NFPA markings and gas detectors can provide an indication of the hazards. Act accordingly.
yes
C1
yes
Look up the name using the appropriate index in the manual.
C1
Is the actual release or threatened release either on land or into water?
no
If a CERCLA release is involved, the substance presumably is a compressed gas and can be found in Table 7.
3
yes
Is the actual release or threatened release into water?
no
If a CERCLA release is involved, the substance presumably is either a solid, whereupon it can be found in Table 6, or it is a liquid and it can be found in Table 5.
4
yes
If a CERCLA release is involved, the substance presumably is either a solid or a liquid and thus can be found in Tables 1, 2, 3, or 4.
5

NOTE: Offpage connectors 3, 4, and 5 can be found in the countermeasure selection flowchart.

FIGURE 1. SITUATION ASSESSMENT FLOWCHART FOR HAZARDOUS SUBSTANCE RELEASES

FIGURE 2. SITE ASSESSMENT CHECKLIST

- o Injured people as result of incident/exposure
- o Fire or threat of fire
- o Name, UN, STCC, or CAS number of substance released
- o Physical state of released substance
  - Solid (vapors present)?
  - Liquid (vapors present?)
  - Gas
- o Source of release - (i.e., tank, truck, railcar, fixed site facility)
- o Approximate volume of release and/or total volume at source
- o Media into which release has occurred and anticipated movement of spill
- o Local terrain/accessibility
  - Topography
  - Porosity of ground surface
  - Distance to population centers and public areas such as schools, churches, public buildings, busy intersections, shopping centers, recreational facilities
  - Distance to drinking water supplies
  - Distance to sewers and watercourses
  - Distance from other hazardous substances
  - Distance to food and feed processing facilities
- o Weather conditions at site
  - Wind speed and direction
  - Air/ground/water temperature, as applicable
  - Precipitation

FIGURE 3. TYPICAL LISTING OF HAZARDOUS SUBSTANCE CHARACTERISTICS:

TABLE A: INSOLUBLE FLOATERS

Hazardous Substance	Chemical Class	CAS No.	Hazard(s), in Addition to Toxicity
Acenaphthylene	Aromatics	208-96-8	Combustible
Allyl chloride	Halides, alkyl, Olephins	107-05-1	Flammable w/toxic products
Amyl acetate	Esters	628-63-7	Flammable
Benzene	Aromatics	71-43-2	Flammable Potential carcinogen
Bis(2-ethylhexyl) phthalate	Esters	117-81-7	
Chloroethane	Aliphatics, halogenated	75-00-3	Flammable w/toxic products
Cumene	Aromatics	98-82-8	Combustible
Cyclohexane	Aliphatics	110-82-7	Flammable
2,4-Dimethylphenol	Phenols and cresols	105-67-9	Combustible
Di-n-octylphthalate	Esters	117-84-0	
Ethyl methacrylate	Esters, Olephins	97-63-2	Flammable Polymerizable
Ethylbenzene	Aromatics	100-41-4	Flammable
Furan	Ethers, Aromatics	110-00-9	Flammable
Isoprene	Olephins	78-79-5	Flammable Polymerizable
N-Nitrosodi-n-propyl-amine	Nitroso compounds	621-64-7	Combustible w/toxic products Potential carcinogen
1,3-Pentadiene	Olephins	504-60-9	Flammable
Saccharin	Sulfones, sulfoxides, a sufonates Aromatics	81-07-2	Potential carcinogen
Styrene	Aromatics Olefins	100-42-5	Flammable Polymerizable
Toluene	Aromatics	108-88-3	Flammable
Xylene	Aromatics	1330-20-7	Flammable

FIGURE 4. TYPICAL LISTING OF HAZARDOUS SUBSTANCE CHARACTERISTICS:
TABLE A: RELEASES IN WATER OF ALL SUBSTANCES

Hazardous Substance	Chemical Class/Guide No	CAS No.	Hazard(s), in Addition to Toxicity	Behavior in Water 'B' Table Reference
Acrylic acid	Acids, organic Olefins	79-10-7	Combustible Corrosive Polymerizable	Soluble Sinker Table 2B
Acrylonitrile	Cyanides and nitriles,	107-13-1	Flammable w/toxic products Polymerizable Potential carcinogen Poison	Soluble Floater Table 4B
Adipic acid	Acids, organic	124-04-9		Soluble Sinker Table 2B
Aldicarb	Esters	116-06-3		Insoluble Sinker Table 1B
Aldrin	Aromatics, halogenated	309-00-2	Combustible w/toxic products Potential carcinogen Poison	Insoluble Sinker Table 1B
Allyl alcohol	Alcohols and glycols, Olefins	107-18-6	Flammable Poison	Soluble Floater Table 4B
Allyl chloride	Halides, alkyl, Olephins	107-05-1	Flammable w/toxic products	Insoluble Floater Table 3B
Aluminum phosphide	Phosphorous and compounds	20859-73-8	Flammable w/toxic products Reactive	Soluble Sinker Table 2B
Aluminum sulfate	Sulfates	10043-01-3		Soluble Sinker Table 2B
5-(Aminomethyl)-3-isoxazole (Note 1)	Amines, alkyl	2763-96-4		Soluble Sinker Table 2B
Amitrole (Note 1)	Azo compounds	61-82-5	Potential carcinogen	Soluble Sinker Table 2B
Ammonium acetate	Organic ammonium compounds	631-61-8		Soluble Sinker Table 2B
Ammonium benzoate	Organic ammonium compounds	1863-63-4		Soluble Sinker Table 2B
Ammonium bicarbonate	Organic ammonium compounds	1066-33-7		Soluble Sinker Table 2B

FIGURE 5, TYPICAL LISTING OF FEASIBLE COUNTERMEASURES

TABLE B: INSOLUBLE FLOATERS

Applicable Countermeasure / Chemical Class	Containment			Displacement		Treatment																						
	Dams, Berms, Dikes	Surface Booms	Curtain Barrier	Skimming	Vacuum Pumping	Absorbents	Granular Media Filtration	Gravity Separation	Evaporation	Steam Stripping	Activated Carbon	Adsorbent Resins	Chemical Dispersion	Extraction	Gels	Ion Exchange	Hydrolysis	Photolysis	Neutralization	Oxidizing Agents	Ozonation	Incineration	Open Burning	Wet Air Oxidation	Biological Treatment	Secondary Wastewater Treatment
Aliphatics	x	x	x	x	x			x	x		x		x		x							x	x		x	x
Aliphatics, Halogenated	x	x	x	x	x			x			x	x			x		x			x		x				
Aromatics	x	x	x	x	x	x	x	x		x	x		x		x			x		x		x	x		x	
Esters	x	x	x	x	x	x		x	x	x	x		x		x		x					x	x		x	
Ethers	x	x	x	x	x	x		x		x	x						x				x	x	x			
Halides, Alkyl	x	x	x	x	x			x			x	x	x		x										x	
Nitroso Compounds	x	x	x	x	x			x								x		x			x					
Olefins	x	x	x	x	x			x			x		x		x							x	x		x	
Phenols and Cresols	x	x	x	x	x			x	x	x	x		x	x	x	x		x	x	x	x	x	x	x	x	
Sulfoxides	x	x	x	x	x		x	x						x		x				x						

Figure 6. TYPICAL COUNTERMEASURE SELECTION CRITERIA
TABLE C : INSOLUBLE FLOATERS

Countermeasures	Potential Extent of Cleanup	Form of HS	Deployment Time	LIMITATIONS: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	LIMITATIONS: Special Access	Unusable in Populated Areas	REQUIREMENTS: Special Equipment	Power	Monitoring	Offsite Disposal/Recycling	Special Safety Precautions	Manpower: Professional	Technician	Unskilled	Permits	Unit Costs (Est.)	Comments
Dams	NA	Neat Diss.	Varies		✓	✓	✓		✓								✓	✓		$4/cu yd	Heavy equipment may require special access. (IV.1.1.1)
Containment booms	NA	Neat	<1 day	✓			✓	✓			✓						✓	✓		$6/ft	Current <2 knots; waves <2-4 feet; difficult to use in high winds; different type for ocean use. (IV.1.1.3)
Curtain barriers	NA	Diss.	<1 day				✓	✓			✓						✓	✓		$200-$300/ ft	Current <1-2 knots; waves <6 feet; depth <25 feet. (IV.1.1.3)
Skimming	Moderate	Neat Diss.	Varies	✓			✓	✓			✓	✓		✓			✓	✓			Explosion-proof and solvent-resistant system necessary. (IV.1.3.3)
Vacuum pumping	Moderate	Neat Diss.	<1 day	✓			✓	✓			✓	✓		✓			✓	✓			(IV.1.3.4)
Absorbents	Gross	Neat	< ½ day	✓	✓			✓			✓			✓	✓		✓	✓			Sorbent must float; may require use of dust mask; type I not for use in high wind; not for use in rain; may be very difficult to contain in rough water; may require special harvesting equipment, e.g., belt skimmer. (IV.2.1)
Granular media filtration	Polish	Diss.	>1 day						✓		✓	✓		✓			✓	✓			(IV.2.3)
Gravity separation	Gross	Neat	<1 day						✓			✓		✓			✓	✓			(IV.2.4)
Evaporation	Gross-moderate	Neat	>1 day			✓	✓			✓		✓			✓				✓		Potential fire/toxic vapor hazard. (IV.2.10)
Steam stripping	Polish	Diss.	>1 day						✓		✓	✓		✓		✓	✓				Requires steam source. (IV.2.8.4)
Activated carbon column	Polish	Diss.	>1 day						✓		✓	✓	✓	✓		✓	✓			2-23¢/gal; carbon 50¢-$5/lb	Will require either disposal or recycling of spent carbon. (IV.3.3.1)
Adsorbent resins	Polish	Diss.	>1 day						✓		✓	✓	✓	✓		✓	✓				(IV.3.1)
Chemical dispersion	NA	Neat	< ½ day													✓	✓	✓	✓		(IV.3.3)

FIGURE 6 (concluded) TYPICAL COUNTERMEASURE SELECTION CRITERIA

TABLE C: INSOLUBLE FLOATERS (concluded)

Countermeasures	Potential Extent of Cleanup	Form of HS	Deployment Time	LIMITATIONS: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	REQUIREMENTS: Special Equipment	Power	Monitoring	Offsite Disposal/Recycling	Special Safety Precautions	Manpower: Professional	Technician	Unskilled	Permits	Unit Costs (Est.)	Comments
Extraction	Moderate	Diss.	>1 day						✓		✓	✓		✓	✓	✓	✓				Solvent may be flammable or have toxic vapors. (IV.3.4)
Gels	NA	Neat Diss.	<½ day	✓	✓	✓	✓	✓						✓	✓		✓	✓		50¢-$2.50/lb	Avoid skin contact and inhalation; currents and rough water may cause difficulty; wind and rain may cause problems with application; cold temperatures may retard gelling time. (IV.3.5.2)
Ion exchange resin column	Polish	Diss.	>1 day						✓		✓	✓	✓	✓		✓	✓				(IV.3.6)
Hydrolysis	Moderate-polish	Neat Diss.	>1 day						✓		✓	✓									(IV.3.7.1)
Photolysis	Polish	Diss.	>1 day						✓		✓	✓									(IV.3.7.2)
Neutralization	Gross Polish	Diss. Neat	<½ day	✓									✓		✓	✓	✓	✓			May cause violent exothermic reaction; wind may make application difficult. (IV.3.8)
Oxidizing agents	Gross Polish	Diss.	>1 day						✓			✓	✓	✓	✓	✓	✓				May require filtration and subsequent disposal of precipitate; strong oxidants must be handled carefully. (IV.3.9.1)
Ozonation	Polish	Diss.	>1 day						✓		✓	✓			✓	✓	✓				Ozone is hazardous to breathe. (IV.3.9.2)
Incineration	Gross Polish	Neat Diss.	<1 day						✓	✓	✓		✓	✓	✓	✓	✓	✓		$8-$25/ton solid; 25¢-$25/ton of liquid	May produce toxic gases; may produce toxic ash which must be disposed of. (IV.4.2)
Open burning	Gross	Neat	<1 day	✓	✓		✓	✓		✓				✓	✓	✓	✓		✓		Fire danger; possible toxic gases/ashes. (IV.4.4)
Wet air oxidation	Moderate Polish	Diss.	<1 day								✓	✓	✓			✓			✓		Not suited for mobile use. (IV.4.7)
Biological treatment	Moderate Polish	Diss.	>1 day			✓					✓					✓			✓	$7.30/1000 gal	Onsite containment and destruction of material possible. (IV.5.0)

FIGURE 7. INDEX TO COUNTERMEASURE DESCRIPTIONS AND COUNTERMEASURE BIBLIOGRAPHY

1.0 Containment and displacement
- 1.1 Containment
  - 1.1.1 Dikes, berms, and dams
  - 1.1.2 Trenches
  - 1.1.3 Booms
    - 1.1.3.1 Surface booms
    - 1.1.3.2 Curtain barriers
  - 1.1.4 Barriers in soil
    - 1.1.4.1 Soil sealants
    - 1.1.4.2 Slurry trenches
    - 1.1.4.3 Sheet piling
  - 1.1.5 Stream diversion
  - 1.1.6 Patching, plugging of containers or vessels
  - 1.1.7 Portable catch-basins
  - 1.1.8 Overpacked drums, containerization
  - 1.1.9 Reorientation of container
- 1.2 Covering and lining
  - 1.2.1 Burial
  - 1.2.2 Encapsulation/grouts
  - 1.2.3 Chemically active covers
  - 1.2.4 Synthetic membrane covers/liners
  - 1.2.5 Foam covers
  - 1.2.6 Inert gas blankets
  - 1.2.7 Liquid covers
- 1.3 Displacement
  - 1.3.1 Dredging
    - 1.3.1.1 Hydraulic
    - 1.3.1.2 Mechanical
  - 1.3.2 Excavation
  - 1.3.3 Skimming
  - 1.3.4 Pumping
  - 1.3.5 Dispersion/dilution
    - 1.3.5.1 Mechanical
    - 1.3.5.2 Chemical
  - 1.3.6 Vacuuming

2.0 Physical treatment
- 2.1 Sorption
  - 2.1.1 Activated carbon
  - 2.1.2 Natural organic sorbents
  - 2.1.3 Natural inorganic sorbents
  - 2.1.4 Synthetic sorbents
- 2.2 Cryogenic cooling
  - 2.2.1 Carbon dioxide
  - 2.2.2 Liquid nitrogen
  - 2.2.3 Water ice
- 2.3 Granular media filtration
- 2.4 Gravity separation
  - 2.4.1 Flotation
  - 2.4.2 Sedimentation

FIGURE 7 (concluded) INDEX TO COUNTERMEASURE DESCRIPTIONS AND COUNTERMEASURE BIBLIOGRAPHY

- 2.4.3 Centrifugation
- 2.4.4 Hydrcyclone
- 2.5 Evaporation
- 2.6 Magnetic separation
- 2.7 Membrane separation
  - 2.7.1 Reverse osmosis
  - 2.7.2 Ultrafiltration
- 2.8 Stripping
  - 2.8.1 Aeration
  - 2.8.2 Steam stripping
- 2.9 Knockdown spray

3.0 Chemical treatment
- 3.1 Coagulation/flocculation
- 3.2 Extraction
- 3.3 Solidification/stabilization
  - 3.3.1 Chelation, sequestration
  - 3.3.2 Cements
  - 3.3.3 Gels
  - 3.3.4 Lime
  - 3.3.5 Organic polymers
  - 3.3.6 Pozzolans
  - 3.3.7 Silicates
  - 3.3.8 Thermoplastics
- 3.4 Ion exchange
  - 3.4.1 Anionic
  - 3.4.2 Cationic
- 3.5 Hydrolysis
  - 3.5.1 Acid hydrolysis
  - 3.5.2 Alkaline hydrolysis
- 3.6 Neutralization
  - 3.6.1 Neutralize w/acid
  - 3.6.2 Neutralize w/base
- 3.7 Oxidation-reduction reactions
  - 3.7.1 Oxidation
  - 3.7.2 Reduction
- 3.8 Polymerization
- 3.9 Precipitaition

4.0 Open burning

5.0 Biological treatment, In-Situ

6.0 Ultimate disposal/destruction
- 6.1 Incineration
- 6.2 Wet air oxidation
- 6.3 Vitrification
- 6.4 Pyrolysis
- 6.5 Biological treatment
- 6.6 Landfill

FIGURE 8. EXCERPT FROM "DESCRIPTION OF COUNTERMEASURES" - START OF SECTION ON "PHYSICAL TREATMENT".

2. Physical treatment processes perform either a phase separation or a component separation of the hazardous substance and the contaminated medium, without chemically transforming or binding the hazardous substance and without adding chemical reagents.

2.1 Absorption is a surface phenomenon which separates a hazardous liquid from a bulk, nonhazardous liquid like water by contact with a solid absorbent. Typical absorbents are inert, nontoxic materials which have small, interconnected interstices or pores that are wetted by the liquid, and to which the liquid clings primarily by surface tension and/or capillary action. Available information indicates that absorbents would be of value for treatment of all land spills and of water spills of some organic materials. Use of absorbents for treatment of water spills will be limited, in most cases, to those substances that are insoluble and float on the water surface.

Absorbents are divided into two general types: natural and synthetic. Natural absorbents consist of natural products such as cellulose, minerals, and other products such as rubber. Synthetic products are made from various organic polymers such as polyurethane, polypropylene, and macroreticular resins, molecular zeolite seives, and amorphous silicates. This section will describe the types of natural and synthetic absorbents; any limitations and use requirements; and identify durable and expendable costs, if available.

2.1.1 Natural Absorbents

Natural absorbents consist of natural products such as cellulose - vegetable and wood fiber, minerals - clays and perlite, and other products such as rubber. Natural materials have been used for years in mitigating oils. However, complete data are not available on their effectiveness for absorbing other organic liquids. Removal of oil-soaked or other organic-soaked natural absorbent is imperative for effective spill treatment. Often these materials are treated to obtain or enhance their hydrophobic characteristics. Natural absorbents are less expensive than synthetic polymers, and though sorption capacity generally increases with the price, the natural absorbents are generally the most cost-effective.

2.1.1.1 Cellulose fibers. Cellulose fibers consist of such materials as treated wood fiber, corn cobs, fiber board, straw, sawdust, bark, peanut hulls, and exotics like Kapok. It is known that natural absorbents such as straw and corn and other types of cellulose fibers will absorb oil and perhaps similar organics from surfaces having thick floating deposits. Desorption from these materials is known to be significant; thus it may be concluded that sorbate retention is poor.

(continued)

FIGURE 9. MAJOR REFERENCE SOURCES ON COUNTERMEASURES

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FIGURE 8 (concluded) EXCERPT FROM "DESCRIPTION OF COUNTERMEASURES"

Absorbent materials derived from natural materials are presumed to be nontoxic, though confirming data are not available. A large amount of these materials introduced into a water body could produce a high biological oxygen demand (BOD) upon degradation by microorganisms. Slowly degradable substances such as lignin-based materials or sawdust, would not be expected to impose as rapid a biological oxygen demand as straw or other highly biodegradable organics. Additional information on cellulose absorbent forms, availability, costs, limitations, and manpower requirements are listed below.

Forms: These materials are available in Type I (particulate form), and may be available as Type II - pillow sorbents, as well as Type III - booms.

Availability: The primary advantage of using cellulose fibers for absorption is availability. These materials can often be easily obtained in isolated rural and urban areas. The only drawback in terms of availability may be seasonal considerations.

Costs: Natural organic sorbents are considered the least expensive of the absorbents. The costs range between $0.01 and $0.02 per pound.

Limitations: Application of Type I (particulate) absorbents is not recommended during windy conditions, any type of precipitation (e.g., rain or snow), or when water conditions are flowing, choppy, or agitated. These materials are recommended for use on land spills and on floating insoluble spills in relatively undisturbed water.

Manpower Requirements: Technicians and unskilled laborers can be effectively utilized in cellulose absorbent application and collection of the used sorbent.